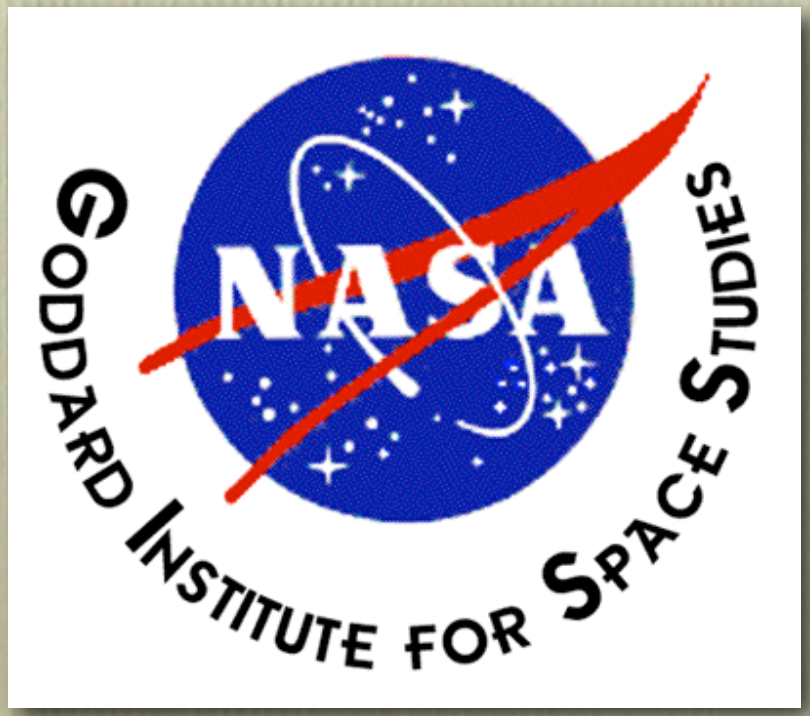
The influence of tropospheric ozone on Arctic climate



Drew Shindell

Greg Faluvegi, Andrew Lacis,
James Hansen, Reto Reudy

History of short-lived species

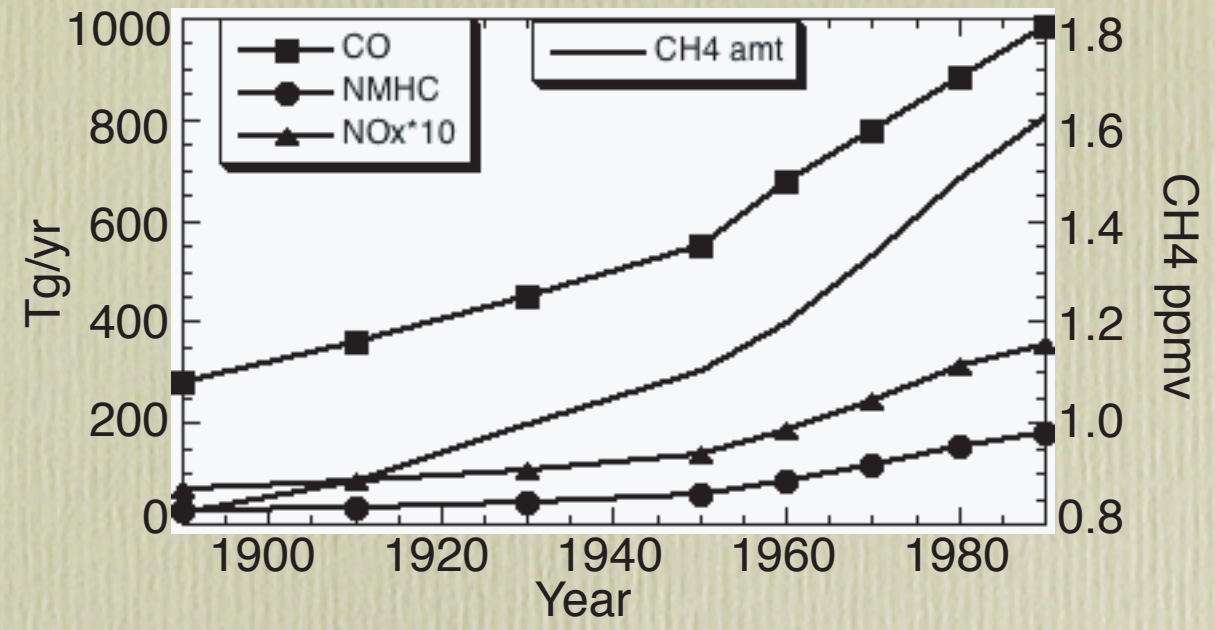
- Very few direct observations
  - 1930s-1950s surface data from the Alps in Europe: ~25 ppbv ozone (vs ~40-50 today), model gets 23-28 depending upon altitude for 1930s, larger for 1950s
  - One 1880s value, model too large (as others)
  - Ozone response probably ok, perhaps conservative
- Model primarily evaluated at present-day
- Must use model driven by estimated historical emissions (unlike WMGHGs)
- Full description in Shindell et al., JGR, 2006.

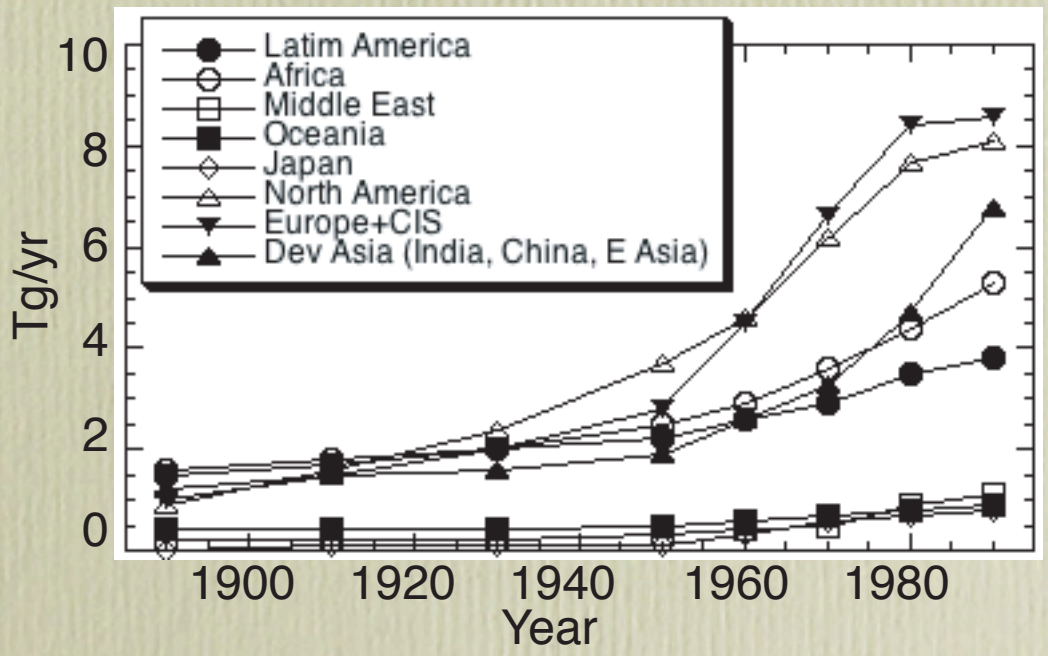
GISS Composition-Climate Modeling

- Ozone photochemistry
  - nitrogen oxides, carbon monoxide, methane, non-methane hydrocarbons are the pollutants that turn into ozone
- Gases fully interactive with climate model (hydrology, radiation, sea ice, etc.)
- 4 x 5 degrees horizontal resolution
- Natural and anthropogenic emissions
  - biomass burning, lightning, forests, wetlands
  - fossil fuel burning, industry, fertilizer, rice, animals

20th Century Emissions

Methane from data, others are estimates!

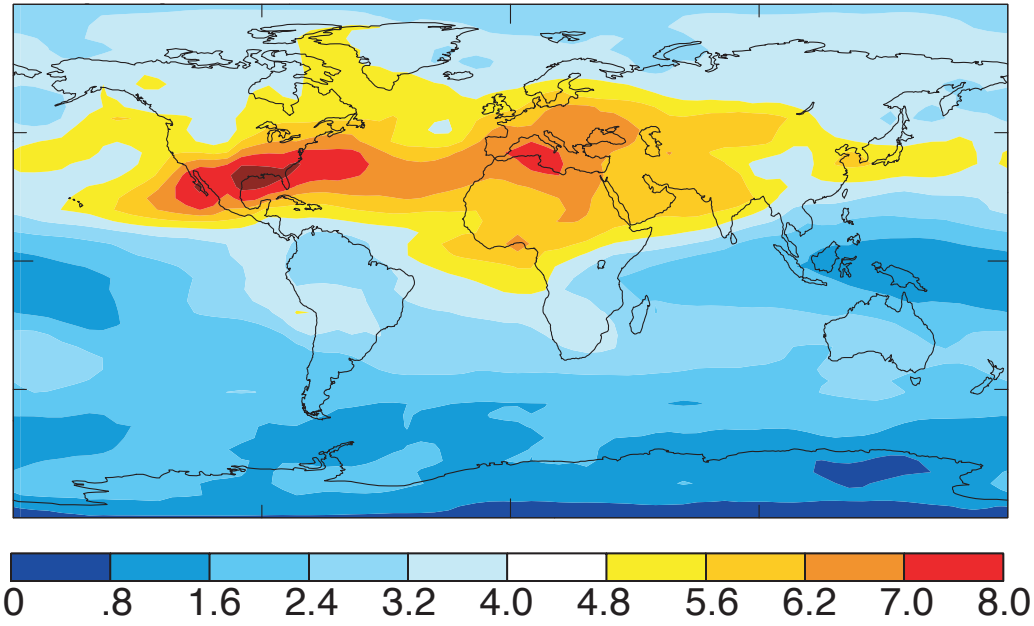




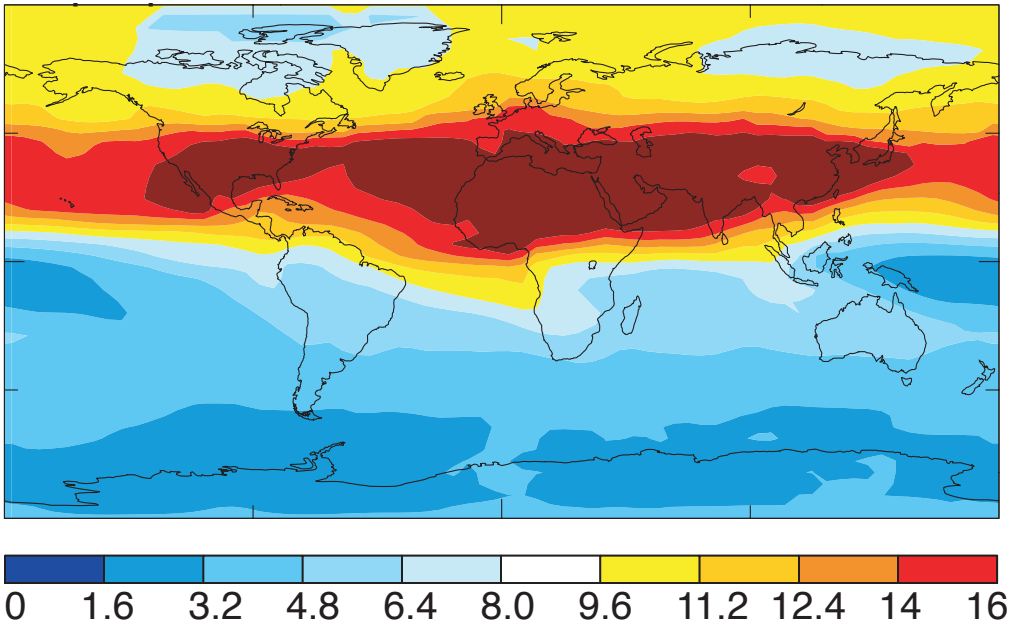
Regional NOx

20th Century Ozone Increases

1890 to 1950



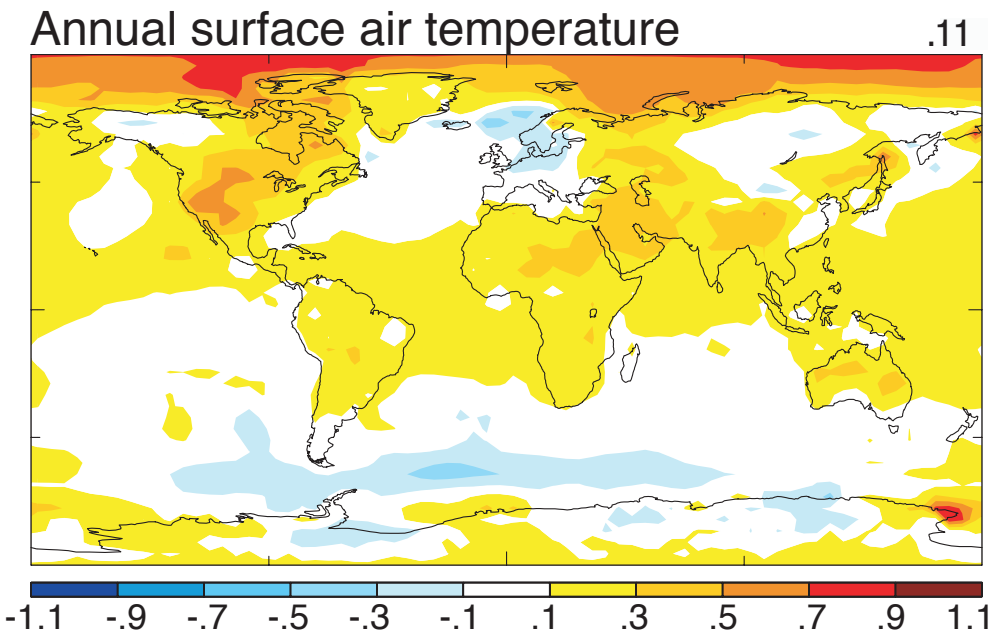
1950 to 1990

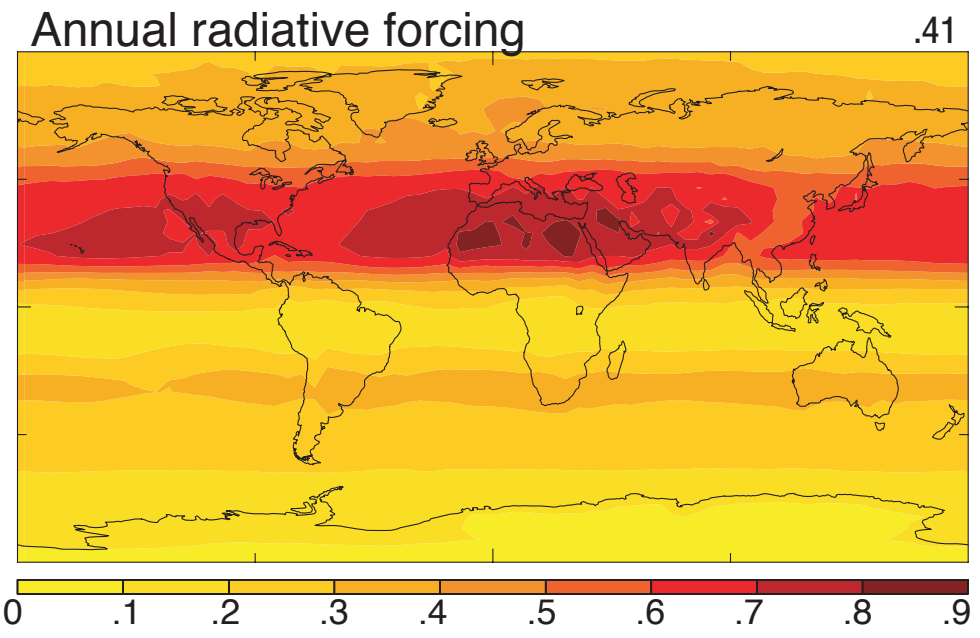


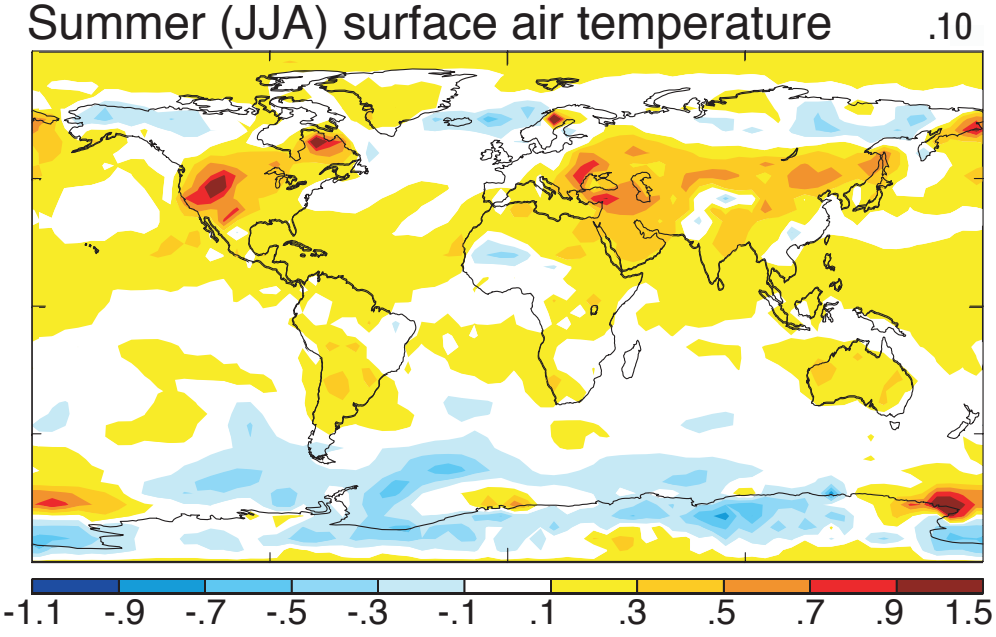
Values are for the tropospheric ozone column
(in Dobson Units)

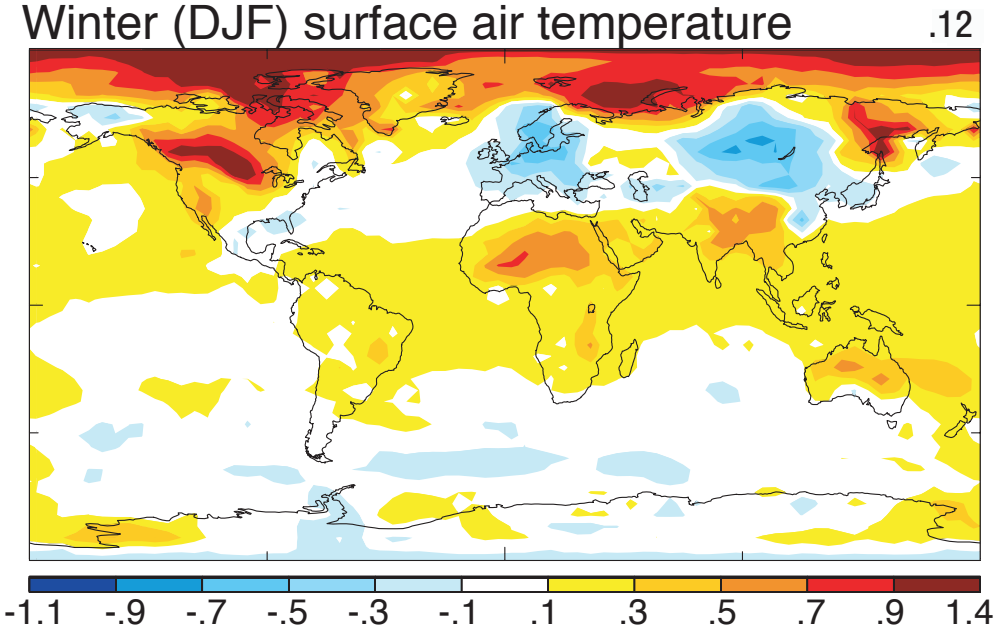
All values are positive. Scale x2 on right.

20th Century Climate response









CATF-GISS Arctic workshop, Jan. 8, 2007

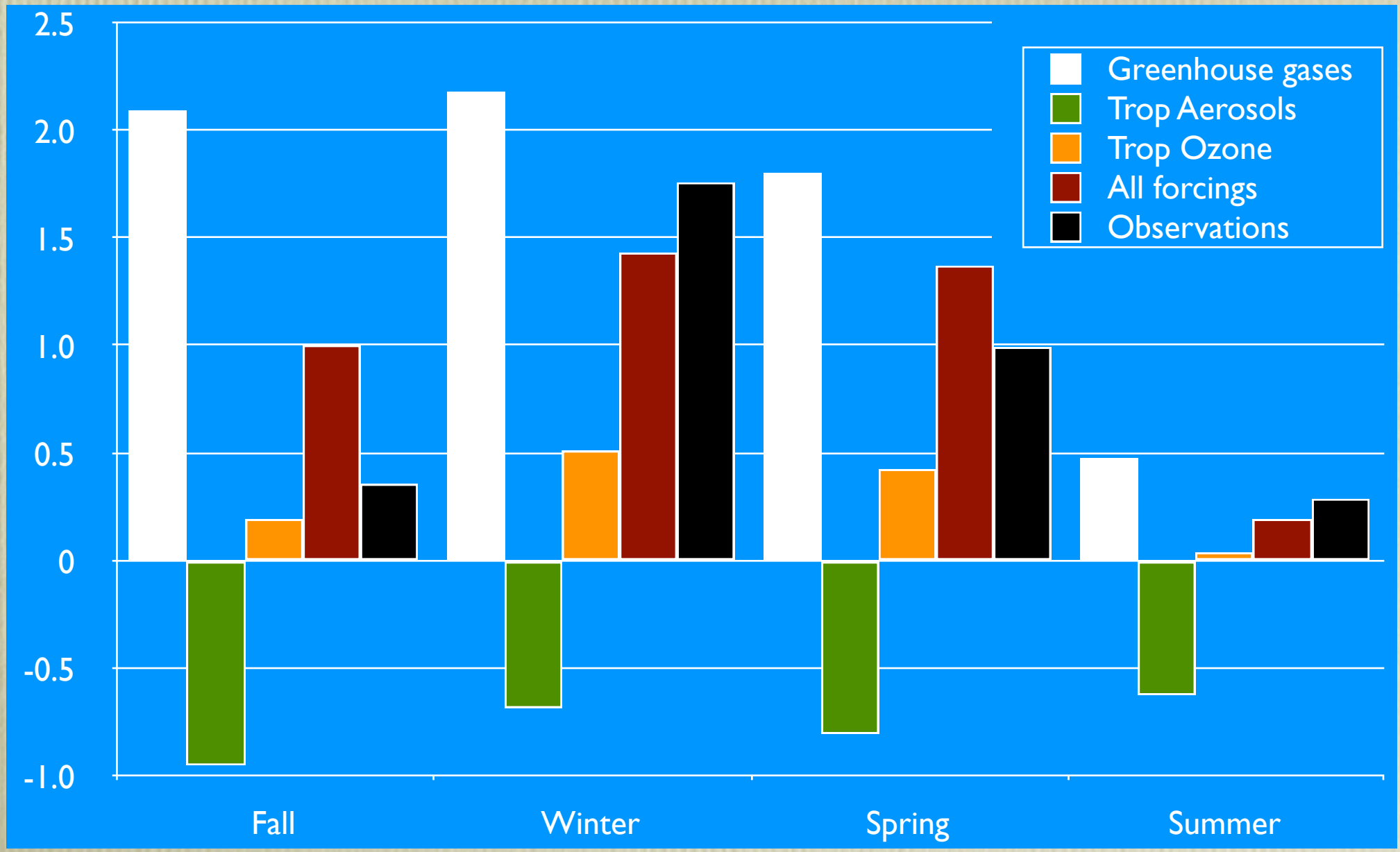
An enhanced effect in the Arctic

- During fall, winter and spring, ozone is long-lived enough to be transported to the Arctic
- Once there, it activates similar feedbacks to other forcings such as ice/snow-albedo positive feedback
- Ozone also has an enhanced effect over bright surfaces as it absorbs reflected radiation (a double greenhouse gas!)
- During summer, strong sunlight breaks up ozone before it reaches the Arctic

1890-2000 IPCC AR4 simulations with the GISS climate model

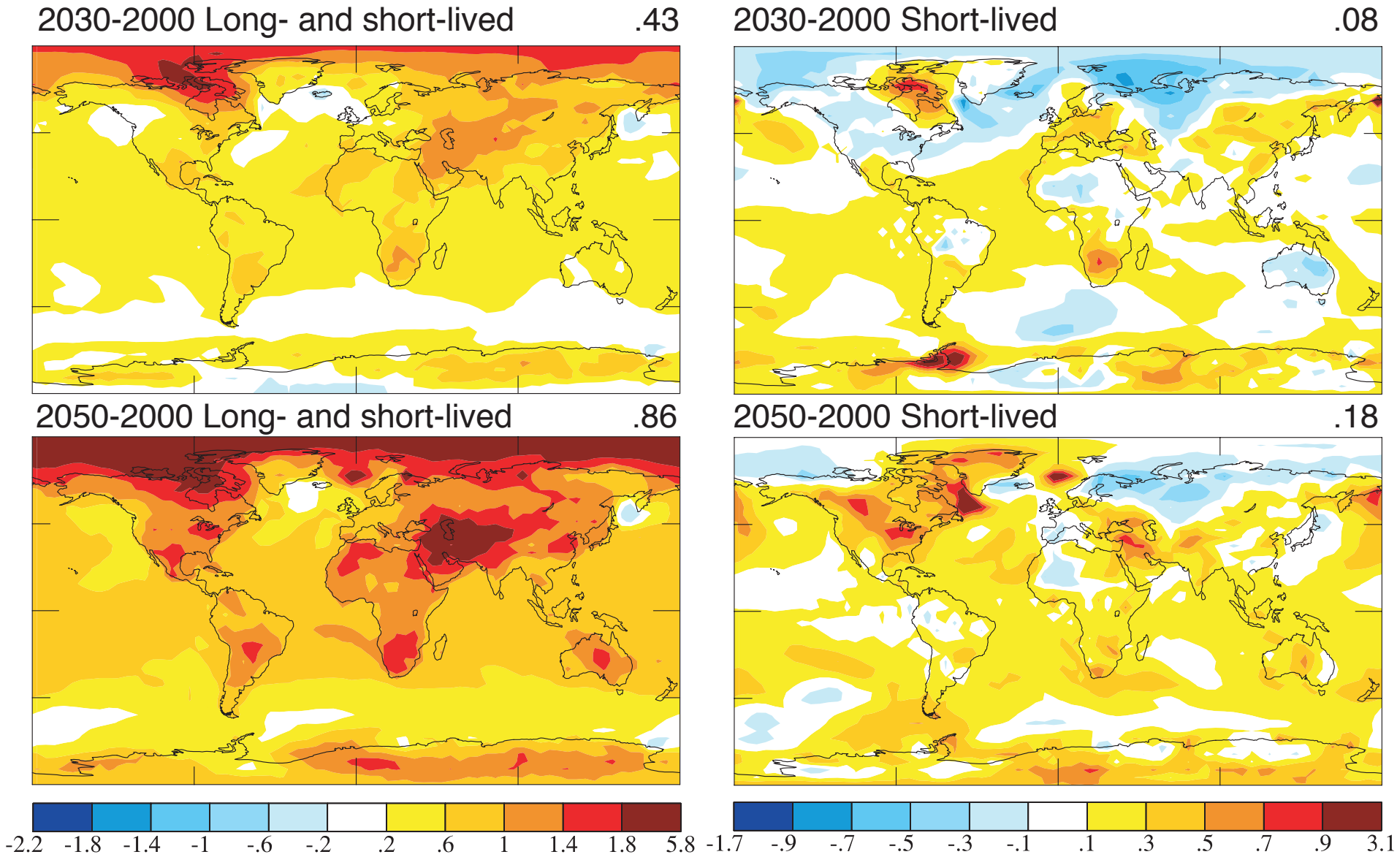
- Well-mixed (long lived) greenhouse gases
- Tropospheric ozone
- Tropospheric aerosols
  - Sulfate
  - Black carbon & organic carbon
  - Nitrate
- All forcings
  - Above plus: stratospheric ozone, volcanic eruptions, solar output, aerosol indirect effects, soot on snow

Arctic Trends from GISS IPCC AR4 Simulations vs Observations

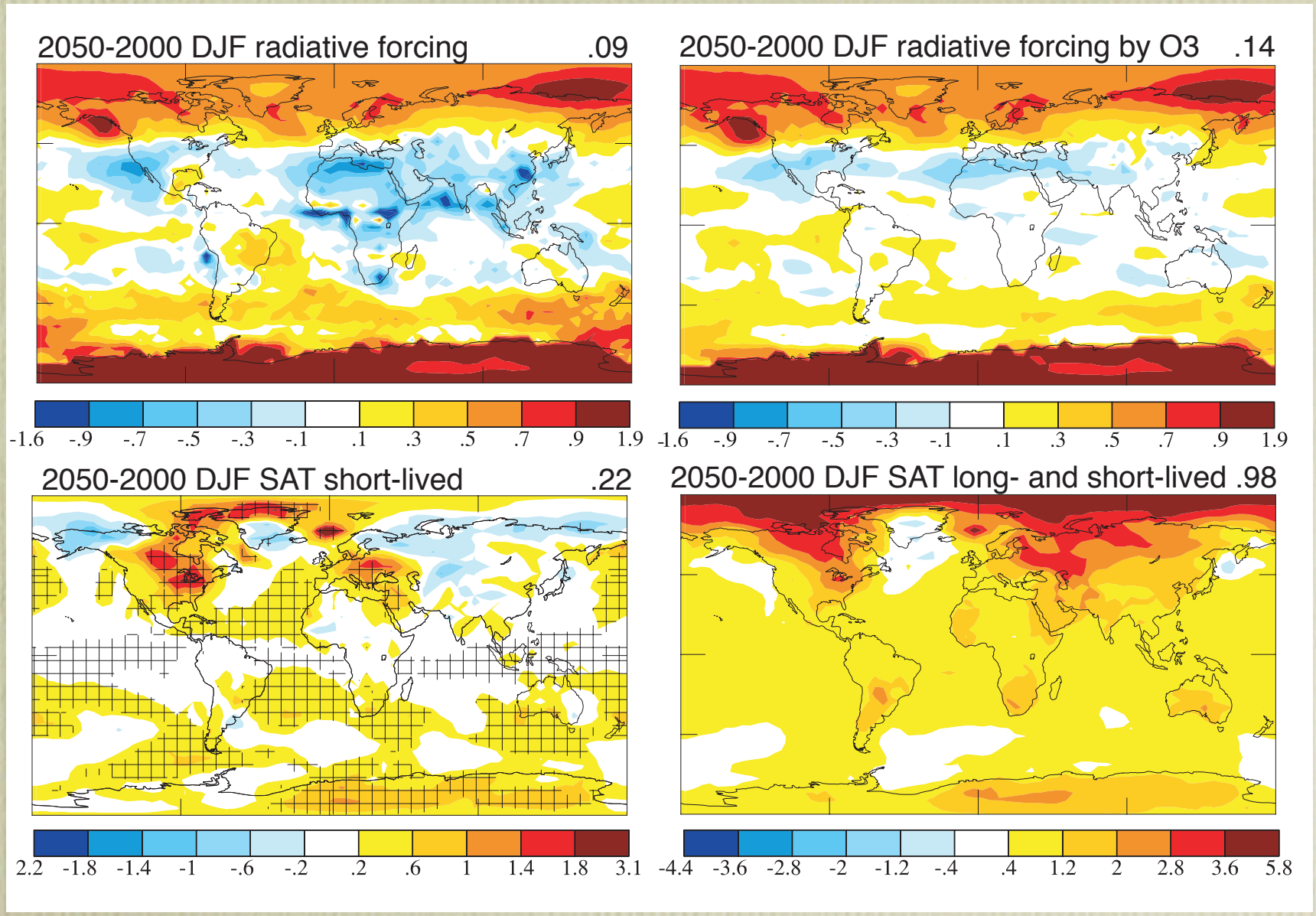


CATF-GISS Arctic workshop, Jan. 8, 2007

CCSP3.2 simulations: Projections with all and just short-lived species (A1B)

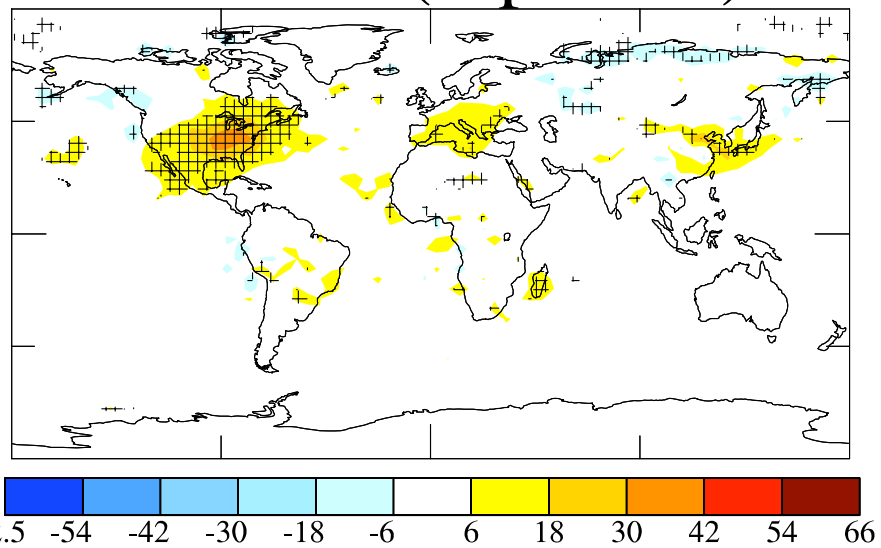


GISS CCSP3.2 results
DJF forcing & response

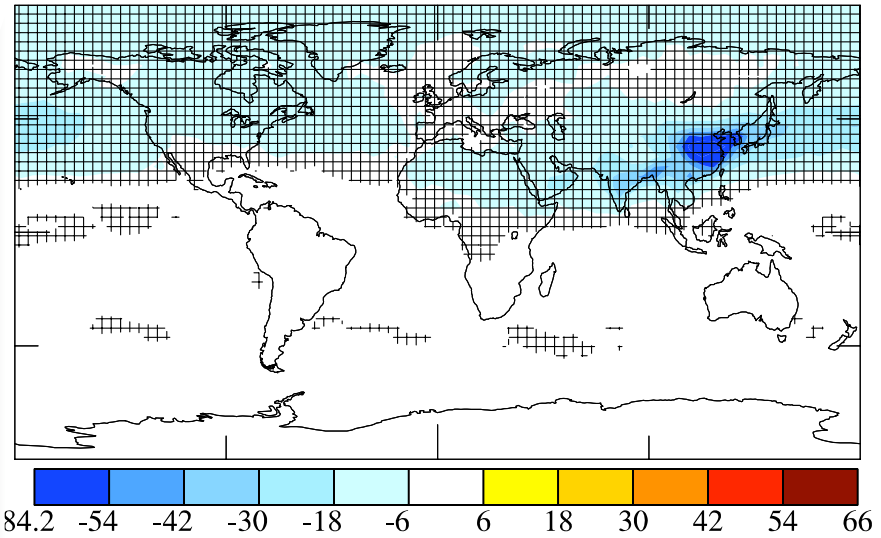


GISS CCSP3.2 sector results
Radiative forcing (mW/m²)

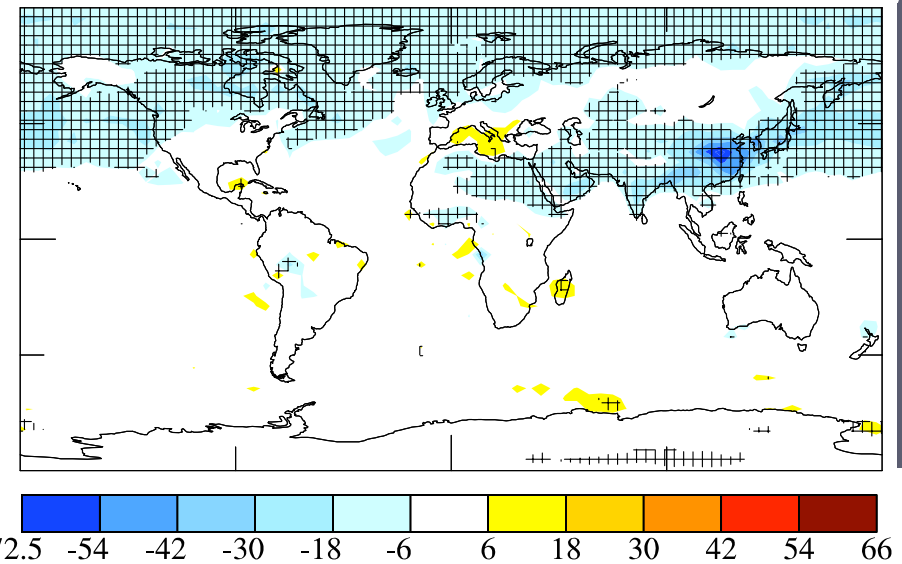
N Amer Ind (esp. SO4)



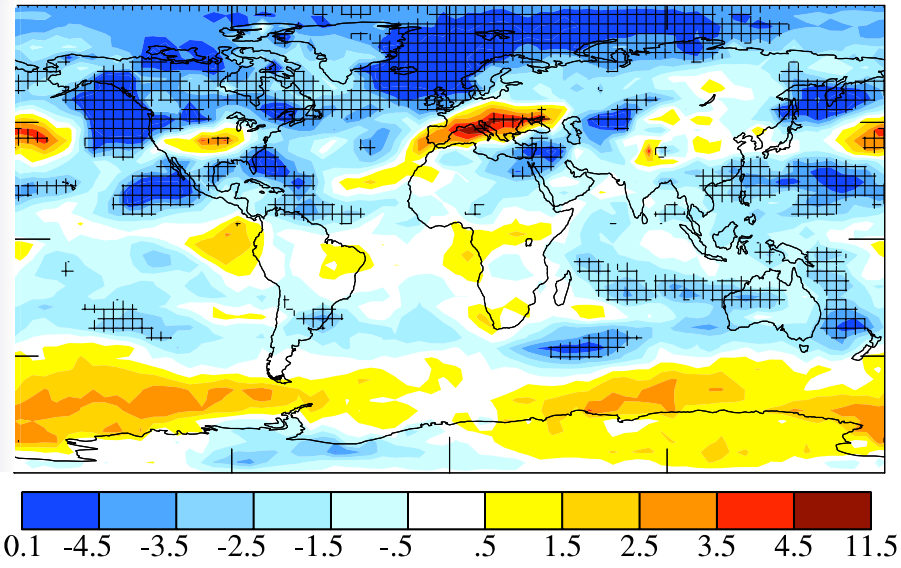
BC (~20 offset from OC)



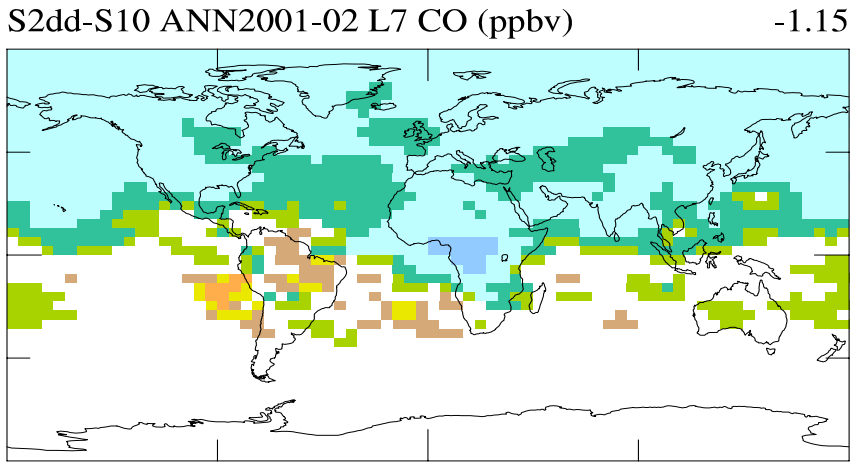
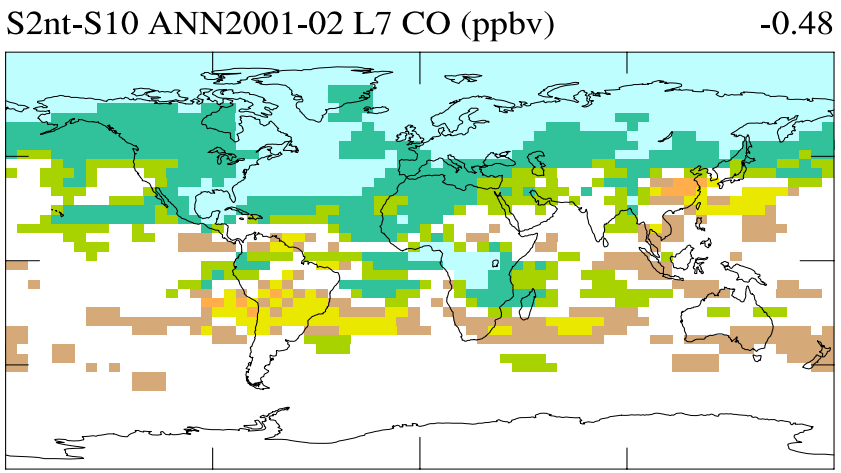
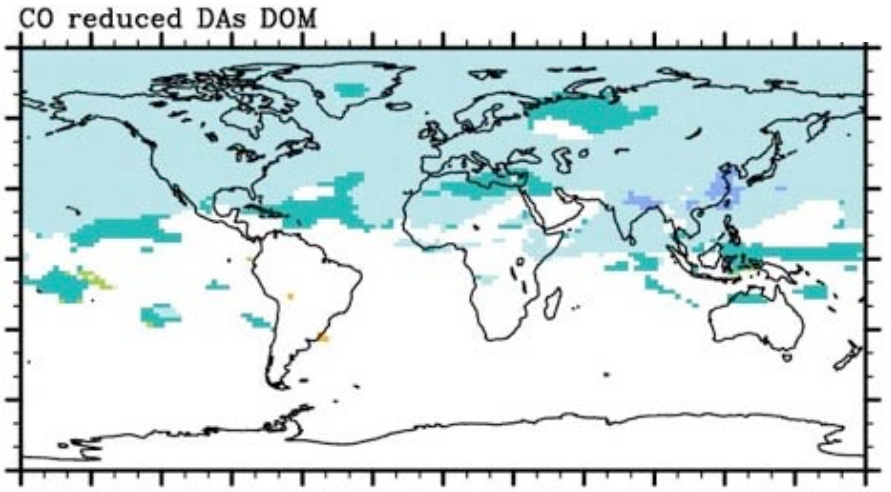
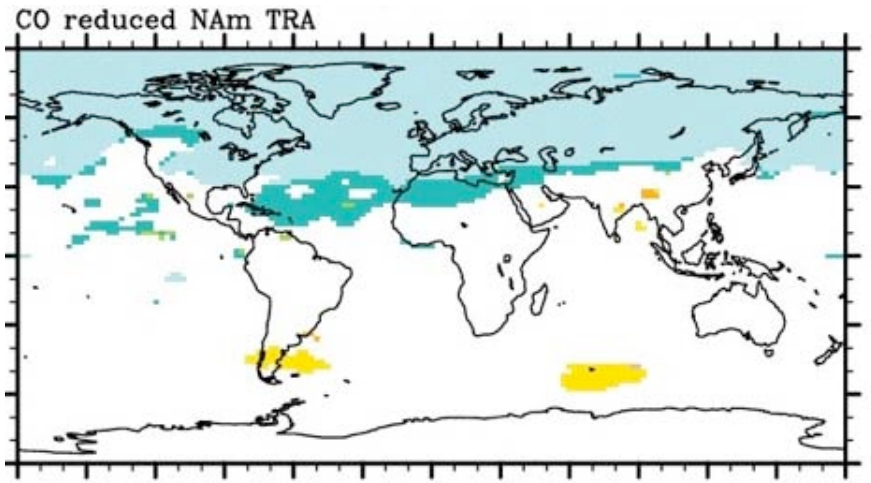
Dev Asia Dom



Ozone



Transport to the Arctic

	Developing Asia, -30% dom/power sector	North America, -30% transport sector
GISS		
NCAR		

Conclusions

- Tropospheric ozone's global mean annual average forcing is about 15% WMGHGs
- This is about 25% of the net forcing
- The Arctic climate response to tropospheric ozone increases during winter and spring is about 25 to 30% that of WMGHGs
- This is about 30-40% of the net response to all forcings
- Substantial Arctic warming from short-lived species projected under A1B during winter and spring
- Sectoral studies indicate Arctic most sensitive to BC, O3
- Targeted pollution controls could have a positive impact on Arctic climate (& human health, agriculture, ecosystems)